Nanowaste classification and management: new emerging waste streams

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Kimberley, Northern Cape

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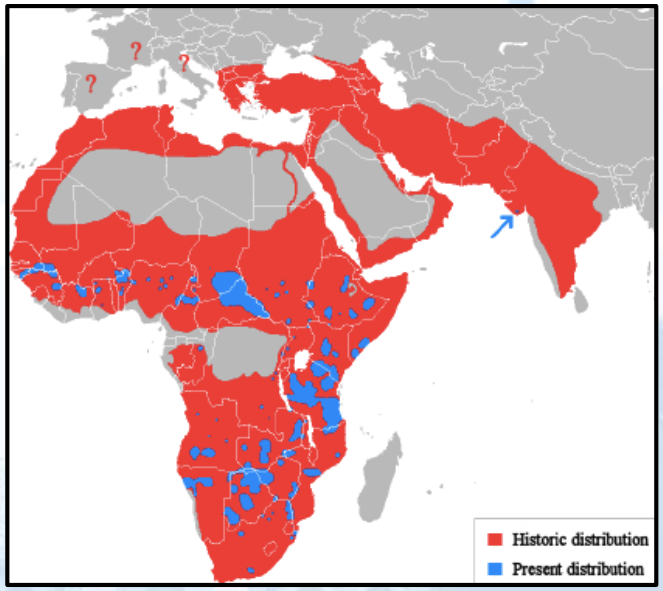
Emerging Contaminants Ecology and Risk assessment (ECERA) Group

Nine planetary boundaries….

- Climate change
- Change in biosphere integrity (***biodiversity loss and species extinction***): last Male Northern Rhino (Sudan) died on 19th March 2018
- Stratospheric ozone depletion
- Ocean acidification
- Biogeochemical flows (phosphorus and nitrogen cycles)
- Land-system change (for example, deforestation)
- Freshwater use
- Atmospheric aerosol loading (microscopic particles in the atmosphere that affect climate and living organisms)
- *Introduction of novel entities (e.g. organic pollutants, radioactive materials, nanomaterials, and micro- and nano-plastics).*



Present and historical distribution of lions….

Ceballos et al., 2017, PNAS, E6089–E60

Rockström et al., Nature 461:472–475, 2009; Steffen et al . 2015. Science 347

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Chemical pollution and the release of novel entities…

- When uptake and bioaccumulation of chemical pollution at sub-lethal levels (***effects at cellular and molecular levels of organization***) on aquatic biology induces ***effects of reduced fertility and potential for permanent genetic damage*** with severe effects on ***ecosystems far removed from the pollution source(s)***

- Moreover, presently inability to quantify a single chemical pollution boundary, despite crossing/exceeding earth system thresholds

- Emergence of novel entities compounds the problem… organic pollutants, radioactive materials, **nanomaterials**, micro- and nano-plastics, and organic electronics

SDGs 12 Goal and Targets

IMPLEMENT THE 10-YEAR SUSTAINABLE CONSUMPTION AND PRODUCTION FRAMEWORK

SUSTAINABLE MANAGEMENT AND USE OF NATURAL RESOURCES

HALVE GLOBAL PER CAPITA FOOD WASTE

RESPONSIBLE MANAGEMENT OF CHEMICALS AND WASTE

SUBSTANTIALLY REDUCE WASTE GENERATION

.....

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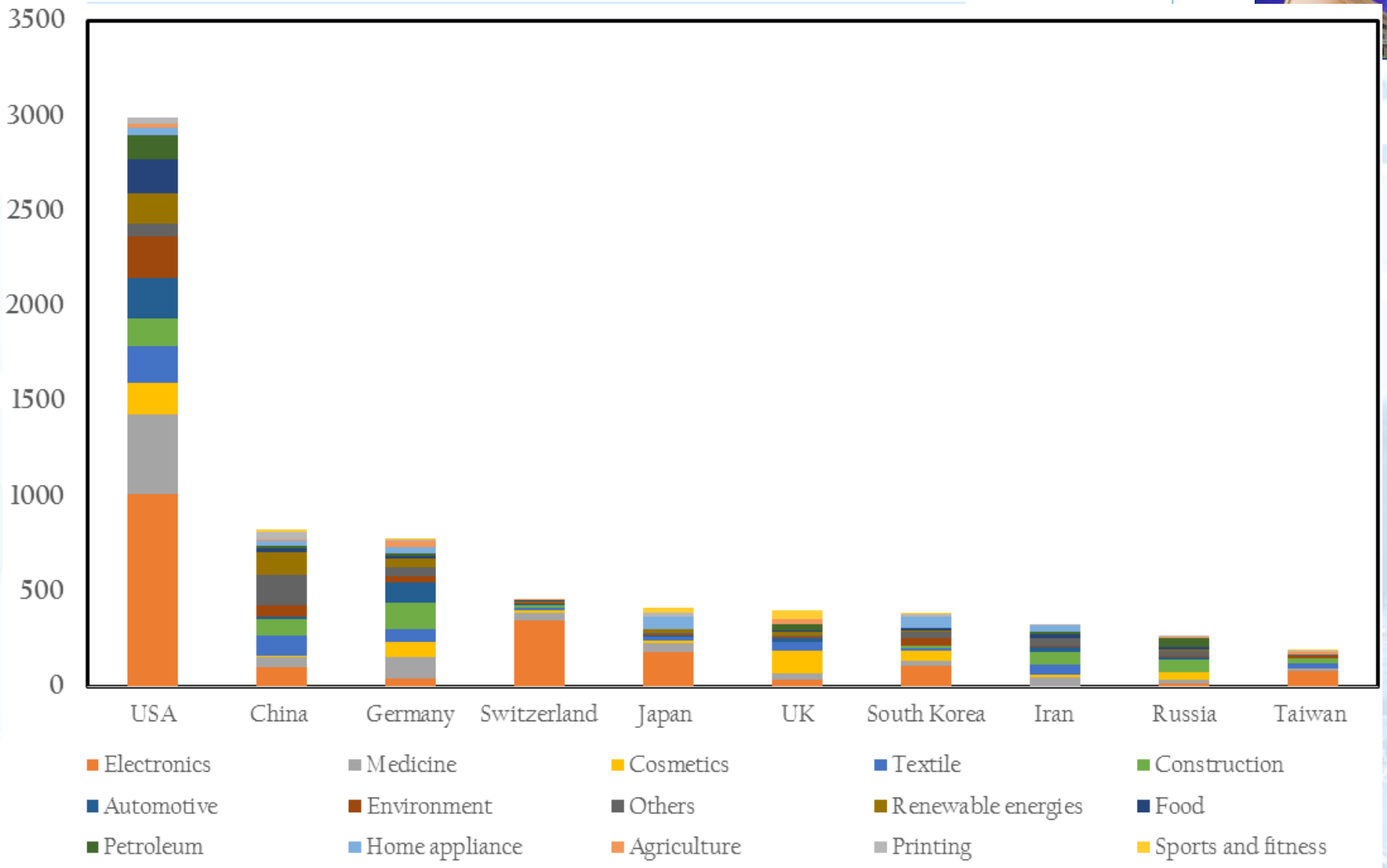
SDG goals: Targets on waste management…

- 12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment

- 12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse

Nanoproducts distribution by country…



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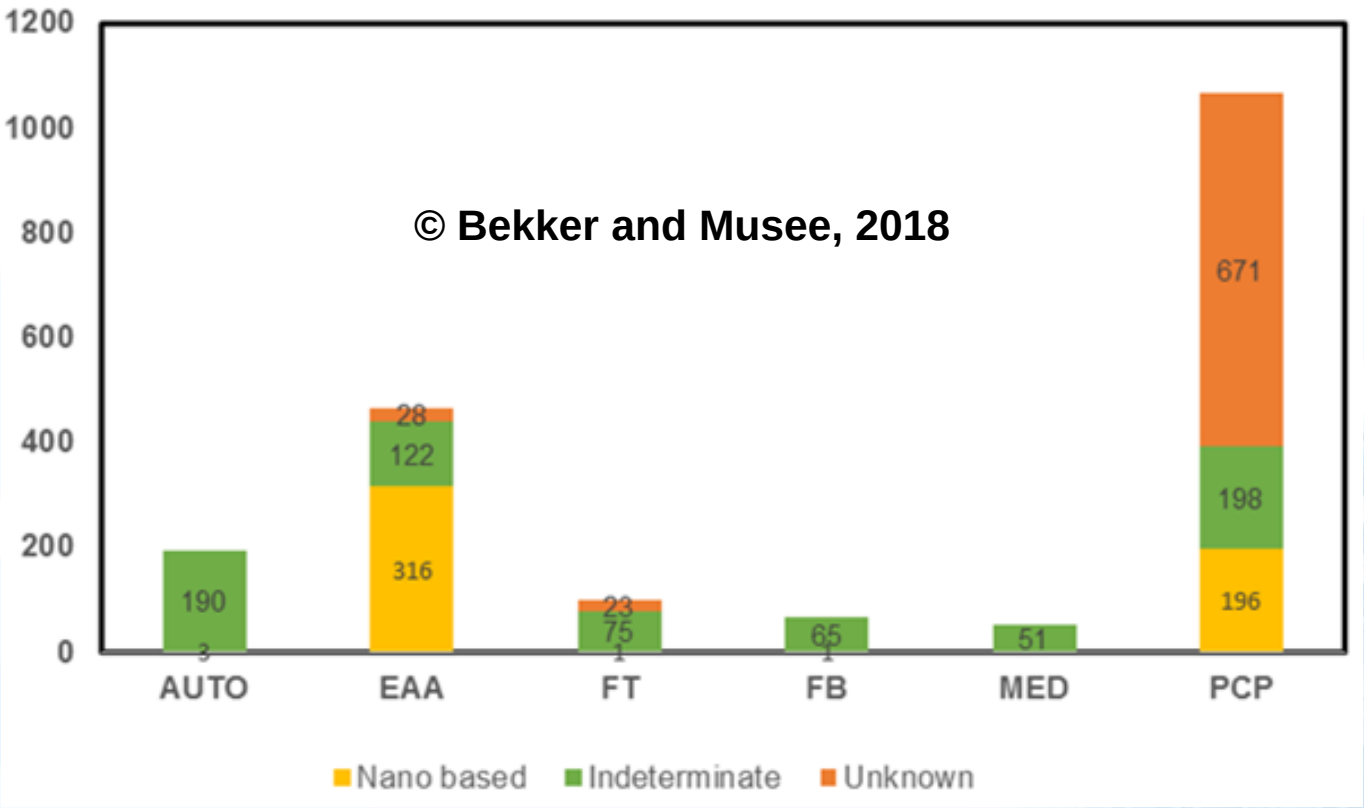
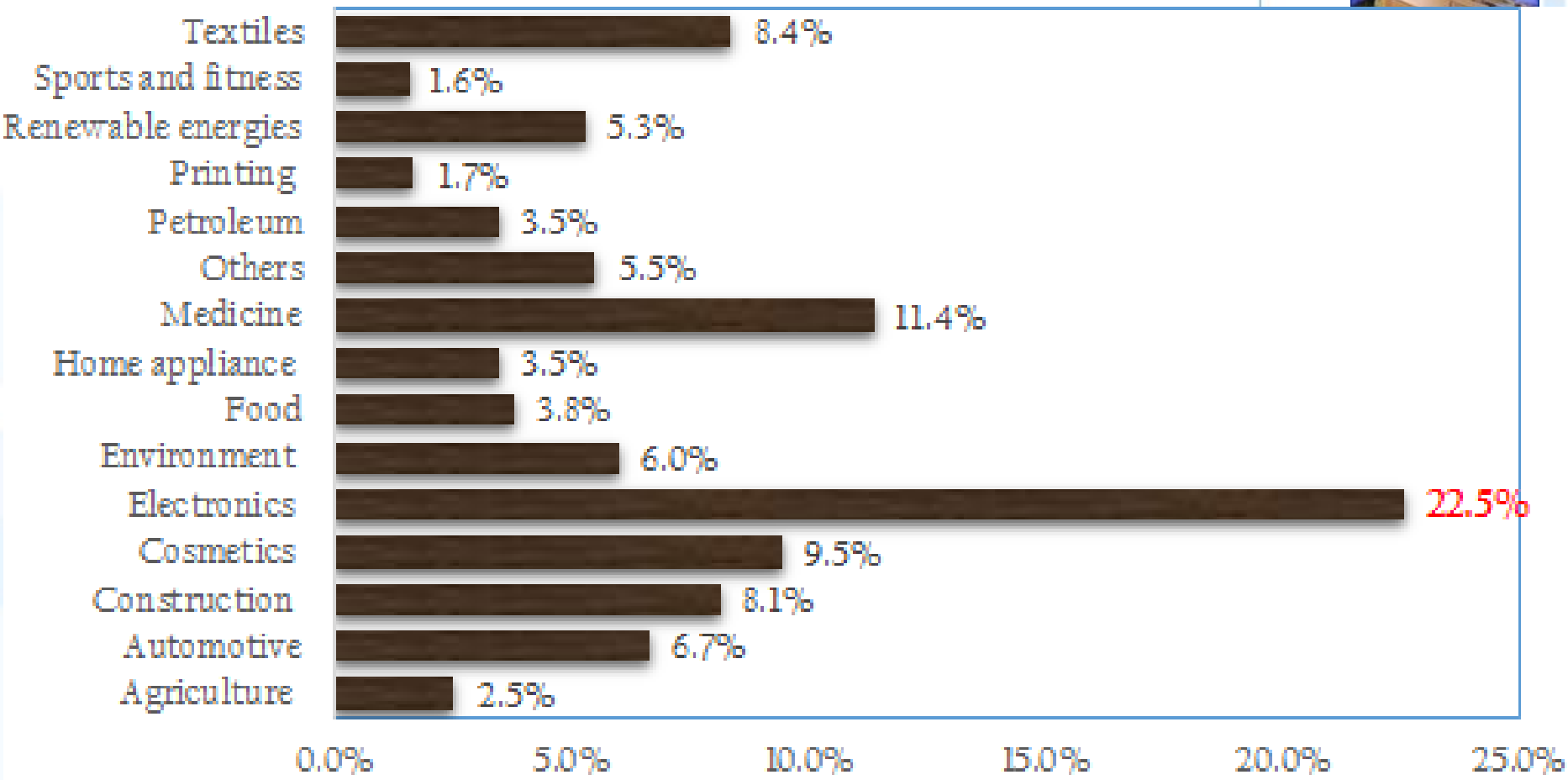
Source: https://product.statnano.com/

Nanoproducts in SA commerce …



AUTO: Automotive;
EAA: Electronics Appliances and Accessories
FT: Fitness and Textiles;
FB: Food and Beverage
HG: Home and Garden;
MED: Medical
PCP: Personal Care Products and Cosmetics

Global nanoproducts distribution by %...



Return Garbage to generators….

Arrive: 2013/4
103 containers
Return: May 2019

China sends waste back to USA

Malaysia sends plastics back to Australia

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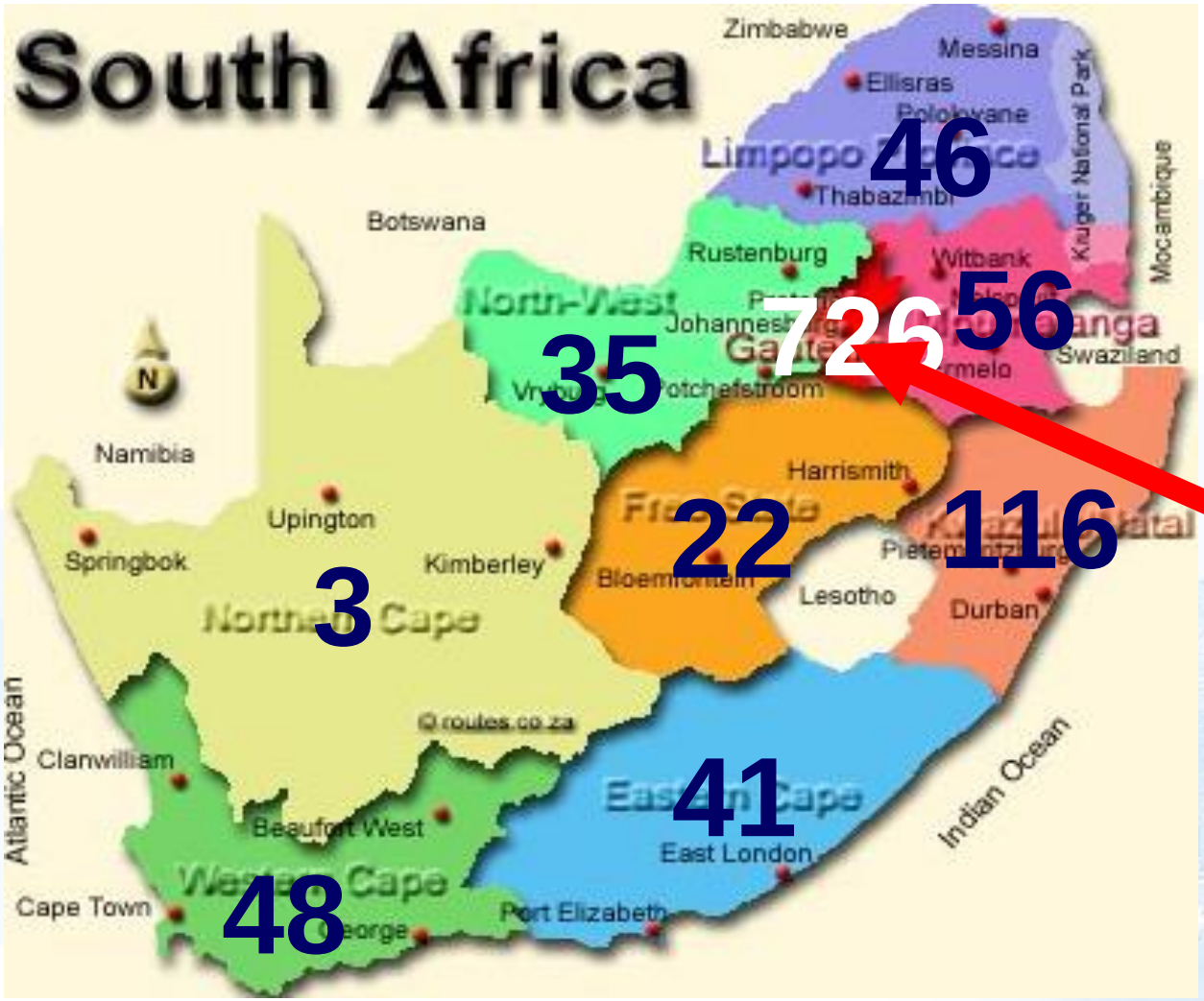
Model assumptions…

- Probability for any sub-product in a given product category are regarded as equal unless differentiated by the number of sub-products and ENMs types used
- Market penetration = population percentage with ability to purchase a given sub-category product and dependent on price; hence levels of market penetration vary from product to product
- Fate and behaviour aspects of ENMs following release into the environment are NOT accounted in our model
- Model aimed to provide insights based on worst case scenario

Social-economic aspects



Region of focus

Nanoproducts in RSA … (2016 RSA inventory)

- Nanoproducts identified were 178 (total)
- Types of nanomaterials : CBNs, and inorganic ENMs (TiO_2, Au, Ag, etc.)
- Nanoproducts contained ***SINGLE*** (167 nanoproducts (≈ 94 %)) and ***MULTIPLE*** ENMs (11 nanoproduct ≈ 6%)
- Major ENMs in RSA Market are: (where each ENM contributes ***≥ 2%***)

ENMs	Percentage
Si	9.6%
Unknown	17.4%
Ti	37.6%
Ag	10.7%
Al	2.2%
CNT	6.7%
TiO2/ZnO	2.8%

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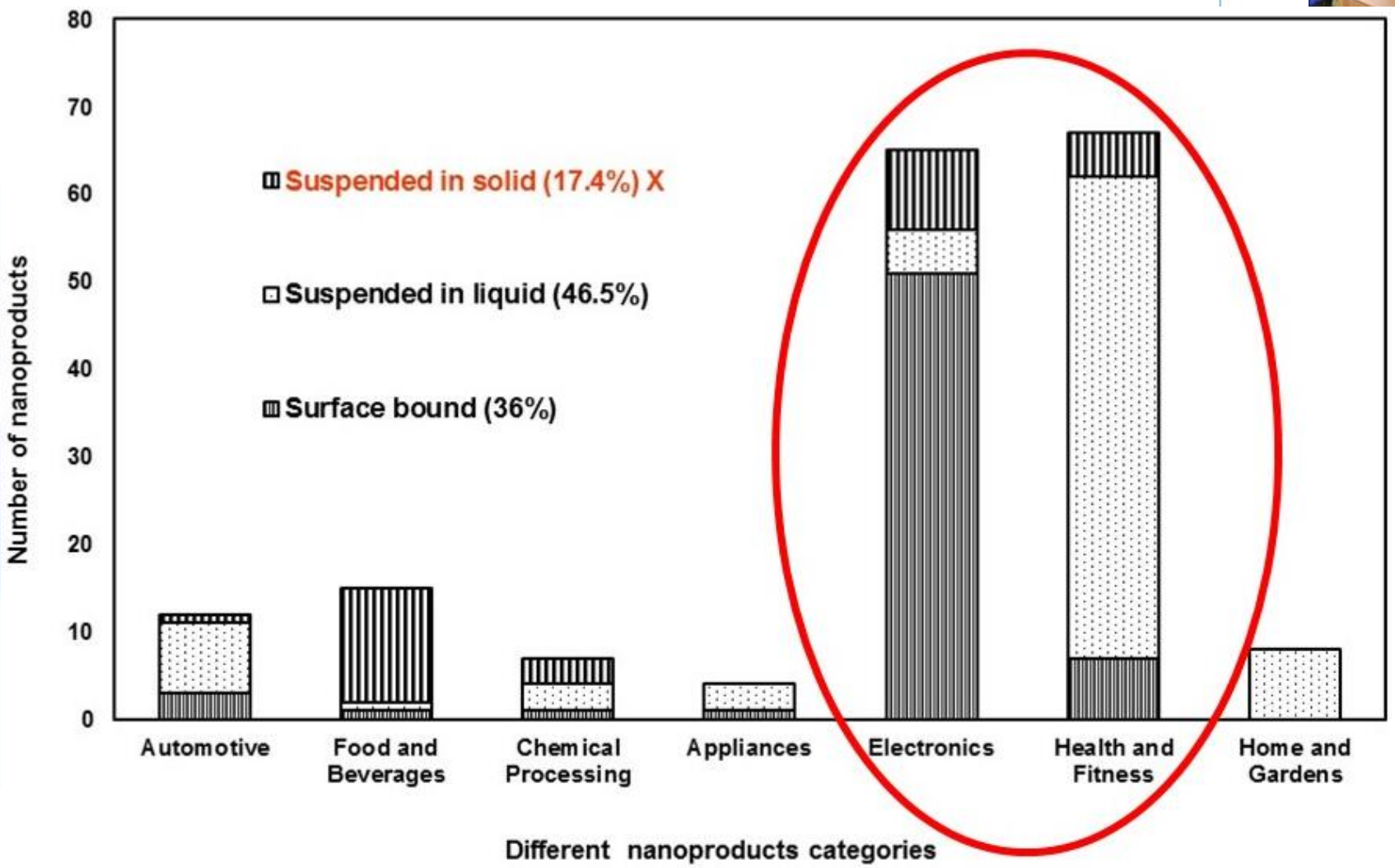
Nanoproduct categories in SA commerce (2016)



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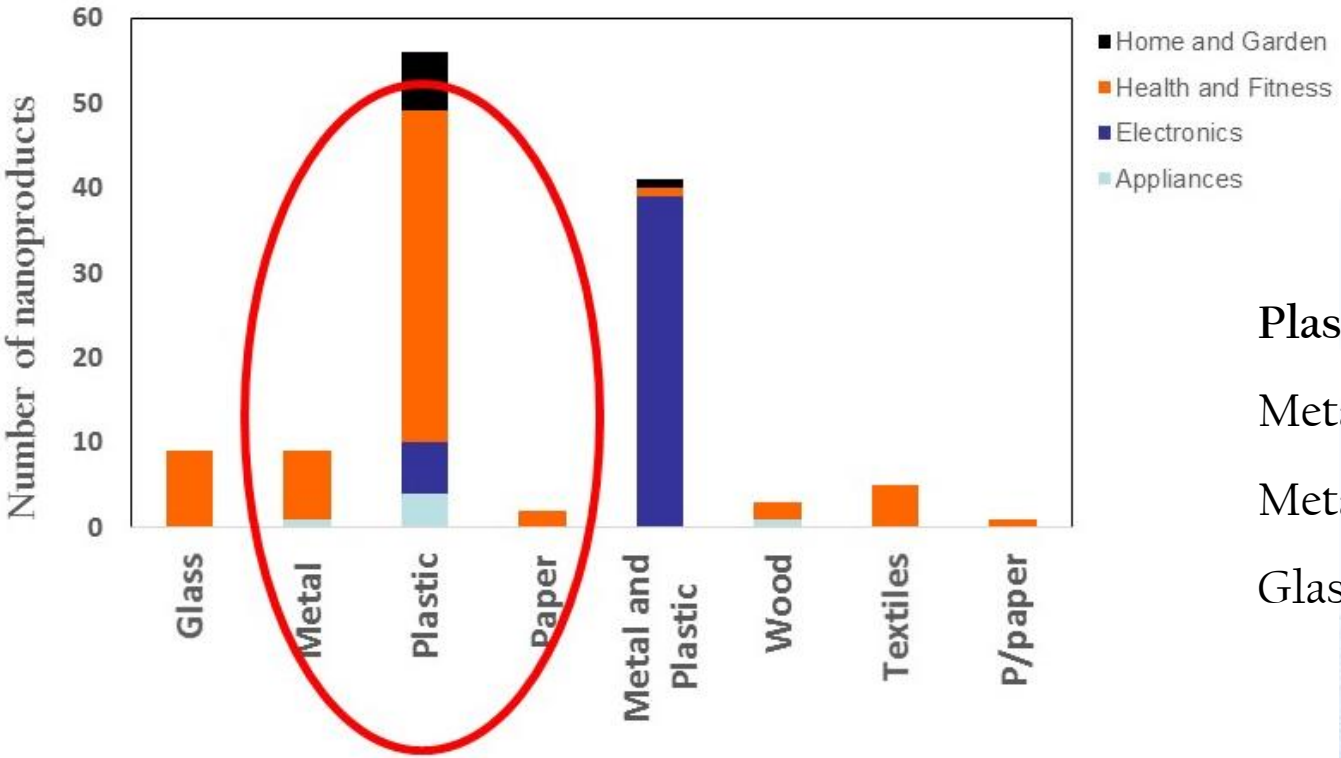
Distribution of solid wastes from nanoproducts



Plastics	**44.40%**
Metal and plastics	32.50%
Metals	7.10%
Glass	7.10%

> 91% of waste

Note: Automotive and Chemical Processing excluded as mainly used in industrial manufacturing processes but not in domestic-used products

Nanoproducts in food and beverage category not included in the analysis. ENMs are in the food, and the link to how they can be transferred onto packaging form of waste streams could not be clearly ascertained

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Distribution of ENMs in health and fitness category

Product	Others	CNTs	Au	TiO_2	Ag	Si	Totals	%
Cosmetics	20	1	2	2	1	3	29	43
Sunscreen	1			7	1		9	13
DUP	2			11	2	1	16	24
Textiles	0	1			4		5	7
Fitness	2	6					8	12
Sub-totals	25	8	2	20	8	4	67	100%

DPU: razor blades, shampoo, shoe polishers, creams, cleansing bars, moisturizers, deodorants, toothpaste, powders

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Trigger(s) based mass of ENMs for data registration

- How will different ENMs be managed when considering the trigger tonnage e.g. AgNPs reported lower masses but has shown to induce high biological effects at very low concentrations to aquatic organisms

- What tonnage threshold will be applicable for ENMs as opposed to values set for bulk materials?

- Test the likely effect of using current mass based thresholds. On waste management it will have no effect when considering the level of risk a given waste stream is likely to trigger

- Based on REACH: For exposure information: among the information required includes: waste quantities and composition of the waste resulting from manufacture and/or use of the products (scarcely lacking: both for products imported and manufactured with ENMs
- Mass as a trigger to evoke need for data collection to carry out risk assessment is linked to production of a given chemical; and in turn, current set values are unlikely to be reached in foreseeable future by ENMs

Similar specifications needed for nanowastes!!!

Table 5 Candidates for registration from inventory of existing chemicals under REACH

Volumes of production or import , per enterprise	>1,000 t/a	100–1,000 t/a	10–100 t/a	>1 t/a
Time for pre-registration	June 1, 2008 Nov 30, 2008	June 1, 2008 Nov 30, 2008	June 1, 2008 Nov 30, 2008	June 1, 2008 Nov 30, 2008
Dead line for registration	Nov 30, 2010	May 31, 2013	May 31, 2018	May 31, 2018
Number of substances which are candidates for registration under REACH	2 693	4 152	7 335	17 500
Substances with highest production volume in this band, % of the total number in this band	100%	70,3%	66,3%	unknown[a]
Substance which have also higher production volumes, % of the total number in this band	[b]	29,7%	33,7%	unknown[a]
Number of registrations, calculated from number of competitors	14,545	7,668	13,513	unknown[a]
Mean number of competitors / substance	5,4	1,8	1,8	< 1,8[c]
% substances with one producer / importer	40%	61%	61%	
% substances with less than 3 producers / importers	67%	92%	91%	>90%[c]
Number of substances with more than 30 competitors	77	3	3	0[c]

[a]No valid data are available how many substances in this band are not produced in higher quantities.
[b]0% by definition because >1,000 ton per annum is the highest band.
[c]Numbers are estimated from experience by the (VCI) German Association of Chemical Industry.

Foth and Hayes: *Hum Exp Toxicol* 2008

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Mass as a trigger: the scoring approach

Bulk chemicals mass based classification		
Production volume (kg)		
< 11 340 (1.1 tonnes)	Very low	1
≥ 11 340 < 453 590	Low	3
≥ 453 590 < 45 359 000	Medium	5
≥ 45 359 000	High	7
Mass for nanoforms		
< 113.4	**Very low**	**1**
≥ 113.4 < 4535.9	**Low**	**3**
≥ 4535.9 < 453 590	**Medium**	**5**
≥ 453 590	**High**	**7**

According to Malkiewicz, et al. Nanomaterials in REACH — project report; 2011. Three categories for chemicals registration: Substances imported/produced:

- >1000 tonnes per annum must have been registered by 30th November 2010
- > 100 tonnes by 31st May 2013
- > 1 tonne by 31st May 2018.
- Proposition for Nanoforms:

=> 1tonne/100 =10 kg

Estimated mass of ENMs to solid waste landfills… in kg

ENMs	CNTs	TiO2	Au	Ag	Si
High	6.48	924.89	12.89	10.81	310.14
Medium	3.49	537.15	6.94	6.38	167.00
Low	1.92	273.91	3.82	3.20	91.85

Conventional chemicals (kg)	Mass (kg) [Nanoform]	Qualitative value	Score
< 11 340 (1.1 tonnes)	< 113.4	Very low	1
≥ 11 340 < 453 590	≥ 113.4 < 4535.9	Low	3
≥ 453 590 < 45 359 000	≥ 4535.9 < 453 590	Medium	5
≥ 45 359 000	≥ 453 590	High	7

Classification of reported effects data for ENMs

Toxicity classes*	ENMs (toxicity classes)**	Fish [96-h LC_{50} (mg/L)]	Crustaceans [48-h EC_{50} (mg/L)]	Algae [72- or 96-h; EC50 (mg/L)	Ranking scores for Toxicity
---------	Extremely toxic	≤ 0.1	≤ 0.1	≤ 0.1	9
Acute I/ Chronic I	Very toxic	≤ 1	≤1	≤1	7
Acute II/ Chronic II	Toxic	1 to ≤ 10	1 to ≤ 10	1 to ≤ 10	5
Acute III/ Chronic III	Harmful	10 to ≤ 100	10 to ≤ 100	10 to ≤ 100	3
Acute IV/ Chronic IV	Not classified/ not harmful	≥ 100	≥ 100	≥ 100	1

*European Commission (EC) 2008. Regulation (EC) No 1272/2008
**Chen et al. (2015) ATLA 43, 221–240
***Studies of Nam et al., (2015) showed Au toxicity to most sensitive organisms.

ECW classes from personal care products….

ENMs	Mass of ENMs		Exposure score		Hazard score	Risk score
	High (kg)	Low (kg)	High	Low		
CNTs	7	2	1	1	1	2
TiO_2	925	274	3	3	5	7
Au	4	3.82	1	1	3	4
Ag	11	3	1	1	9	10
Si	310	92	3	**1**	1	3

RSA context …

- Nanoproducts are in SA market but also ECW in the landfills!!
- Likely low masses of ENMs released into landfills: model predictions
- Imported products in RSA are major sources of ENMs into the environment but with limited national capability to deal with such waste streams
- Increasing ECW streams as products developed have shorter use span
- Need for monitoring of ENMs in landfills in SA

…. and way forward

- Consider other trigger(s) besides mass to invoke data collection…for ENMs
- Landfill will host multiple ENMs, and therefore, consideration for mixtures is essential
- Explore the use of toxicity factors between nanoforms and counterpart bulk materials to find new mass related triggers may be a possibility… remain an open question

Thank you

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